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ORIGINAL ARTICLE

Selection of empirical antibiotics for health care-associated pneumonia via integration of pneumonia severity index and risk factors of drug-resistant pathogens

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Background/purpose: The pneumonia severity index (PSI) both contains some risk factors of drug-resistant pathogens (DRPs) and represents the severity of health care-associated pneumonia. The aim of this study was to investigate whether the PSI could be used to predict DRPs and whether there were risk factors beyond the PSI.
Methods: A retrospective observational study enrolled 530 patients with health care-associated pneumonia who were admitted from January 2005 to December 2010 in a tertiary care hospital.
Results: A total of 206 patients (38.9%) had DRPs, of which the most common was *Pseudomonas aeruginosa* (24.3%). The incidence of DRPs increased with increasing PSI classes (6.7%, 25.5%, 36.9%, and 44.6% in PSI II, III, IV, and V, respectively). An analysis of the risk factors for DRPs by PSI classes revealed that wound care was associated with methicillin-resistant *Staphylococcus aureus* (MRSA) infection in PSI V ($p = 0.045$). Nasogastric tube feeding (odds ratio, 3.88; 95% confidence interval, 1.75–8.60; $p = 0.006$), and bronchiectasis (odds ratio, 3.12; 95% confidence interval, 0.66–14.69; $p = 0.007$) were risk factors for DRPs in PSI III and IV. The area under the receiver operating characteristic curve progressed from 0.578 to 0.651 while integrating these risk factors with PSI classes.
Conclusion: The findings suggested that PSI plus risk factors predicted the risk of DRPs. PSI II had a low risk of DRPs and could be treated as community-acquired pneumonia. Antibiotics

Conflicts of interests: The authors have no conflicts of interest relevant to this article.

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of PSI III and IV with risk factors could be targeted DRPs. PSI V with wound care had a higher risk of MRSA, and empirical anti-MRSA antibiotics could be added.

Introduction

Obtaining microbiological information as quickly as possible remains a challenge when treating patients with pneumonia. Pneumonia is classified as community-acquired pneumonia (CAP) and hospital-acquired pneumonia (HAP), which suggests the possible pathogens and therefore the choice of antibiotics in the early phase of the treatment for pneumonia.[1,2] However, several studies have reported that some CAP patients are at a greater risk of gram-negative bacteria and pathogens resistant to conventional CAP antibiotics.[3–5] The 2005 American Thoracic Society/Infectious Disease Society of America (ATS/IDSA) guidelines first defined the subgroup of CAP as health care-associated pneumonia (HCAP), and recommended broad-spectrum antibiotics similar to those used for HAP.[6] However, some studies do not suggest the use of empirical broad-spectrum antibiotics because HCAP is actually a heterogeneous group.[7] Predicting the occurrence of drug-resistant pathogens (DRPs) at diagnosis is one of the most important issues in patients with HCAP, thereby avoiding inadequate or overuse of broad-spectrum antibiotics. Several risk factors for DRPs in HCAP, including hospitalization in the past 90 days, recent antibiotic therapy in the past 6 months, poor functional status, and immune suppression, have been reported.[7–10]

According to the 2005 ATS/IDSA guidelines for HAP, ventilator-associated pneumonia, and HCAP, the selection of empirical antibiotics should take into consideration the risk factors for DRPs, but not include the severity of the patient's disease.[6] However, according to studies of CAP, stratification of the severity of disease can guide decisions on the site of care and also the selection of antibiotics.[11,12] Therefore, we hypothesized that the severity of HCAP would be correlated with DRPs. However, there are currently no well-accepted methods to evaluate the severity of HCAP. Some investigators have shown that predictive scoring systems, such as the pneumonia severity index (PSI) or CURB-65, can also be used with HCAP.[13,14] Because risk factors suggestive of DRPs[10,15] overlap with some items of the PSI, we planned to use the PSI to evaluate the severity of HCAP. We conducted this retrospective observational study at a tertiary care hospital. The primary end-point was the correlation between PSI and DRPs. The secondary end-point was to identify whether there were additional risk factors for DRPs beyond the PSI.

Materials and methods

Patients who were admitted to our 800-bed tertiary care hospital in Taiwan, from January 2005 to December 2010, were screened by discharge diagnosis. The medical records of the patients whose primary discharge diagnosis was pneumonia (International Classification of Diseases codes 482, 485, and 486) were reviewed. The patients were enrolled if they fulfilled the criteria for HCAP,[6] which were defined as follows: patients who had been hospitalized in an acute care hospital for ≥ 2 days within the past 90 days; residents of a nursing home or long-term care facility; recipients of recent intravenous antibiotic therapy, chemotherapy or wound care within the past 30 days; or patients who attended a hospital or hemodialysis clinic. Because of the uncertain clinical course, the patients who had been transferred from other hospitals after hospitalization were excluded. The Institutional Review Board of the Far Eastern Memorial Hospital, New Taipei City, Taiwan approved this study (IRB 102013-E).

The definition of steroid use was a daily steroid dose of > 10 mg lasting for > 3 months. Chronic kidney disease was defined as an estimated glomerular filtration rate < 30 mL/min without the need for hemodialysis. Chemotherapy was defined as having undergone chemotherapy within 60 days for a malignancy. Although arterial blood gas data were not available in some patients, arterial partial pressure of oxygen was considered to be < 60 mmHg if oxygen saturation measured by pulse oximetry was $< 90\%$ in room air. The data on causative pathogens were obtained from sputum cultures and/or the cultures of sterile specimens within 24 hours after the diagnosis of pneumonia had been established, e.g., from blood or pleural effusion. The data of sputum culture were reported in a semiquantitative manner. Possible causative pathogens were identified from sputum if the collected sputum samples were of sufficient quality, defined as > 25 polymorphonuclear cells and < 10 epithelial cells per power field with a total magnification $\times$ 100, and a moderate or heavy amount of growth in the cultures. DRPs were defined as those not sensitive to the antibiotics suggested for CAP treatment, such as β-lactam, macrolide, and respiratory fluoroquinolones.[12] The initial antibiotic treatment was classified as being inappropriate if the initially prescribed antibiotics were not active against the identified pathogens based on *in vitro* susceptibility testing.[15] Antibiotics against *Pseudomonas aeruginosa* and methicillin-resistant *Staphylococcus aureus* (MRSA) were defined as the broad-spectrum antibiotics. PSI scores and grouping were calculated according to the principles of the Pneumonia Patient Outcomes Research Team cohort study on CAP.[16] PSI is based on age and the presence of coexisting disease including neoplastic disease, liver disease, renal disease, cerebrovascular disease, and congestive heart failure, abnormal physical findings (such as respiratory rate, body temperature, pulse, blood pressure), and mental status as well as abnormal laboratory and radiographic findings (blood pH, urea nitrogen concentration, blood sugar, hematocrit, sodium concentration, arterial oxygen partial pressure, or pleural effusion) at presentation. Severity was classified into four groups as follows: PSI class II ($\leq$ 70), III (71–90), IV (91–130), and V (> 130).

All data were expressed as mean $\pm$ standard deviation unless otherwise stated. Statistical analysis was performed using SPSS version 18 software (SPSS Inc., Chicago, IL, USA). Continuous data were compared using Student t test, and categorical data including demographics, outcomes, antibiotics, and microbiology were compared using Mann–Whitney U test. Odds ratios (ORs) and their 95% confidence intervals (CIs) were calculated. The relationship between the PSI and DRPs was calculated using analysis of variance. The validity of the PSI and the predictive ability were evaluated using receiver operating characteristic (ROC) curves. A p value < 0.05 was considered to indicate statistical significance.

Results

Patient demographics

During the study period, 1633 patients were admitted with a primary discharge diagnosis of pneumonia, of whom 530 (32.5%) met the criteria of HCAP. The demographic and morbidity data are shown in Table 1. The most common criterion of HCAP was past admission within 90 days, followed by recipients of antibiotics within 90 days and residing in a nursing home. The most prevalent morbidity was cerebrovascular illness.

When stratified by PSI score, the PSI class II patients were significantly younger than the other patients (49.7 +/− 14.5 v.s. 75.8 +/− 12.0 $p < 0.001$). Chronic steroid use and hemodialysis were more prevalent in PSI class II patients than in PSI class IV and V patients ($p < 0.001$). However, more patients with PSI class IV and V resided in nursing homes compared to patients with PSI class II and III ($p < 0.001$). The most significant difference in comorbidities between PSI classes was cerebrovascular illnesses ($p < 0.001$). This represented that patients with PSI class IV and V were in poor functional status.

Microbiology

As shown in Table 2, only 35 (6.6%) patients had positive blood culture results. There was no significant difference in the prevalence of positive blood culture results between the patients with PSI class III–V. The leading pathogen was *Klebsiella pneumoniae* followed by *Escherichia coli*. The incidence of MRSA was 8.5% in patients with bacteremia.

The causative agents are shown in Table 3. Causative microorganisms were identified in 286 (48%) patients. Among these patients, 35 (12.2%) were identified by blood culture, 73 (25.5%) by endobronchial tube aspiration, and the other 178 (62.7%) by sputum culture. The three most common pathogens were *P. aeruginosa* (24.3%), *K. pneumoniae* (8.3%), and *Haemophilus influenzae* (7.9%). A total of 206patients (38.9%) had DRPs. The leading pathogens of DRPs were *P. aeruginosa*, MRSA, *Stenotrophomonas maltophilia*, and *Acinetobacter baumannii*.

Table 1 Demographic and morbidity characteristics.

	Total (N = 530)	PSI II (N = 15)	PSI III (N = 51)	PSI IV (N = 195)	PSI V (N = 269)
Age (y)	75.1 ± 12.8	49.7 ± 14.5*	66.4 ± 11.7	73.3 ± 12.5	79.5 ± 10.2
Sex (M/F)	349/181	10/5	31/20	139/56	169/100
ICU	116 (21.9)	1 (6.7)	3 (5.9)	15 (7.7)	97 (36.1)
Admission within 90 d	317 (59.8)	5 (33.3)	30 (58.8)	124 (63.6)	158 (58.7)
Nursing home	224 (42.3)	2 (13.3)*	8 (15.7)	82 (42.1)	132 (49.1)
Antibiotics within 30 d	123 (23.2)	4 (26.7)	14 (27.5)	38 (19.2)	67 (24.9)
Antibiotics within 90 d	232 (43.8)	4 (26.7)	19 (37.3)	84 (43.1)	125 (46.5)
Active chemotherapy	47 (8.9)	3 (20)	4 (7.8)	21 (10.8)	19 (7.1)
Steroid use	63 (11.9)	4 (26.7)*	9 (17.6)	37 (19)	13 (4.8)
Wound care	103 (19.4)	1 (6.7)	7 (13.7)	40 (20.5)	55 (20.4)
Hemodialysis	48 (9.1)	4 (26.7)*	11 (21.6)	14 (7.2)	19 (7.1)
CVA, n (%)	264 (49.8)	0	1 (2)	95 (48.7)	168 (62.5)**
Malignancy	140 (26.4)	3 (20)	8 (15.7)	45 (23.1)	85 (31.6)
DM	220 (41.5)	5 (33.3)	17 (33.3)	70 (35.9)	128 (47.6)
CKD	89 (16.8)	2 (13.3)	9 (17.6)	25 (12.8)	54 (20.1)
Heart failure	84 (15.8)	2 (13.3)	4 (7.8)	26 (13.3)	52 (19.3)
COPD	191 (36)	2 (13.3)	17 (33.3)	74 (37.9)	98 (36.1)
Bronchiectasis	27 (5.1)	1 (6.7)	6 (11.7)	10 (5.1)	10 (3.7)
Liver cirrhosis	20 (3.8)	0	0	5 (2.6)	15 (5.6)

Data are presented as n (%) or mean ± SD, unless otherwise indicated.
*$p < 0.001$ PSI II versus PSI III, IV, and V.
**$p < 0.001$ PSI II, III versus PSI IV and V.
CKD = chronic renal disease; COPD = chronic obstructive pulmonary disease; CVA = cerebrovascular illnesses; DM = diabetes mellitus; ICU = the care of intensive care unit during the first 3 days of admission; PSI = pneumonia severity index.

Table 2 Pathogens identified by blood culture.

	Total (N = 530)	PSI II (N = 15)	PSI III (N = 51)	PSI IV (N = 195)	PSI V (N = 269)
Blood culture	35 (6.6)	0 (0)	4 (7.8)	10 (5.1)	21 (7.8)
Gram positive					
Streptococcus pneumoniae	4 (0.8)	0 (0)	1 (2.0)	0 (0)	3 (1.1)
MSSA	2 (0.4)	0 (0)	0 (0)	0 (0)	2 (0.7)
MRSA	3 (0.6)	0 (0)	0 (0)	0 (0)	3 (1.1)
β-Streptococcus	3 (0.6)	0 (0)	0 (0)	1 (0.5)	2 (0.7)
Gram negative					
Klebsiella pneumoniae	8 (1.5)	0 (0)	2 (3.9)	1 (0.5)	5 (1.9)
Escherichia coli	6 (1.1)	0 (0)	1 (2.0)	0 (0)	5 (1.9)
Haemophilus influenzae	2 (0.4)	0 (0)	0 (0)	1 (0.5)	1 (0.4)
Proteus mirabilis	1 (0.2)	0 (0)	0 (0)	1 (0.5)	0 (0)
Pseudomonas aeruginosa	2 (0.4)	0 (0)	0 (0)	2 (1.0)	0 (0)
Acinetobacter baumanni	3 (0.6)	0 (0)	0 (0)	3 (1.5)	0 (0)
Chryseobacterium	1 (0.2)	0 (0)	0 (0)	1 (0.5)	0 (0)

Data are presented as *n* (%).
MSSA = methicillin-sensitive *S. aureus*; MRSA = methicillin-resistant *S. aureus*; PSI = pneumonia severity index.

Table 3 Causative organisms of health care-associated pneumonia.

	Total (N = 530)	PSI II (N = 15)	PSI III (N = 51)	PSI IV (N = 195)	PSI V (N = 269)
Pathogens sensitive to CAP antibiotics regimen					
Streptococcus pneumonia	16 (3.0)	0	4 (7.8)	7 (3.6)	5 (1.9)
MSSA	13 (2.5)	0	0	4 (2.1)	9 (3.3)
β-Streptococcus	15 (2.8)	0	1 (2.0)	5 (2.6)	9 (3.3)
Klebsiella pneumoniae	42 (7.9)	1 (6.7)	2 (3.9)	15 (7.7)	24 (8.9)
Escherichia coli	18 (3.4)	0	0	7 (3.6)	13 (4.8)
Haemophilus influenzae	42 (7.9)	0	4 (7.8)	17 (8.7)	21 (7.8)
Moraxella catarrhalis	1 (0.2)	0	0 (0)	1 (0.5)	2 (0.7)
Morganella morganii	5 (0.9)	0	0 (0)	3 (1.5)	2 (0.7)
Proteus mirabilis	23 (4.3)	0	4 (7.8)	6 (3.1)	13 (4.8)
Enterobacter cloacae	16 (3.0)	0	4 (7.8)	4 (2.1)	8 (3.0)
Serratia marcescens	33 (6.2)	0	1 (2.0)	13 (6.7)	19 (7.1)
Pathogens resistant to CAP antibiotics regimen					
MRSA	37 (7.0)	0	3 (5.9)	9 (4.6)	25 (9.3)
Klebsiella pneumoniae	2 (0.4)	0 (0)	0 (0)	1 (0.5)	1 (0.4)
Escherichia coli	8 (1.5)	0 (0)	0 (0)	5 (2.6)	3 (1.1)
Proteus mirabilis	2 (0.4)	0 (0)	0 (0)	1 (0.5)	1 (0.4)
Pseudomonas aeruginosa	129 (24.3)	1 (6.7)	9 (17.6)	46 (23.6)	73 (27.1)
Acinetobacter baumannii	25 (3.7)	0	1 (2.0)	7 (3.6)	17 (6.3)
Stenotrophomonas maltophilia	22 (4.2)	0	1 (2.0)	6 (3.1)	15 (5.6)
Chryseobacterium	1 (0.2)	0 (0)	0 (0)	1 (0.5)	0 (0)

Data are presented as *n* (%).
CAP = community-acquired pneumonia; MSSA = methicillin-sensitive *S. aureus*; MRSA = methicillin-resistant *S. aureus*.

Incidence of DRPs and in-hospital mortality in the PSI groups

The incidence of DRPs (6.6%, 25.5%, 36.9%, and 44.6% in PSI II, III, IV, and V, respectively) and in-hospital mortality rate (0%, 5.9%, 12.3%, and 23.8%, respectively) increased with increasing PSI classes (Fig. 1). The area under ROC curve of the PSI was 0.578 (95% CI, 0.529—0.627) to predict DRPs and 0.632 (95% CI, 0.574—0.690) to predict the in-hospital mortality.

Risk factors of DRPs beyond PSI

The rate of inappropriate antibiotic treatment was not significantly different among the various PSI groups. However higher in-hospital mortality rates were noted in patients who received inappropriate antibiotic treatment in the PSI III and IV groups (20% and 22.6%, respectively) compared to those with appropriate antibiotic treatment [2.4% (PSI III) and 10.4% (PSI IV), p = 0.036 and p = 0.058, respectively], as shown in Fig. 2. However, the in-hospital mortality rates in the PSI V group were similar regardless

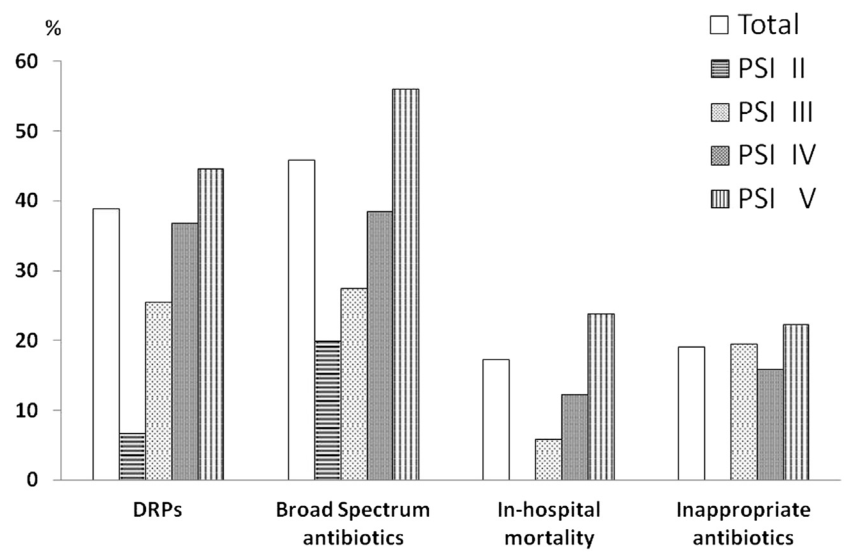

Figure 1 Incidences of multiple-drug resistant pathogens, broad-spectrum antibiotics, in-hospital mortality, and inappropriate antibiotic use among PSI classes. The incidences of drug resistant pathogens, broad-spectrum antibiotic use, and in-hospital mortality rate increased with increasing PSI score. The rate of inappropriate antibiotic use was not significantly different among the PSI III—V classes. DRPs = pathogens resistant to the treatment regimen of community acquired; PSI = pneumonia severity index.

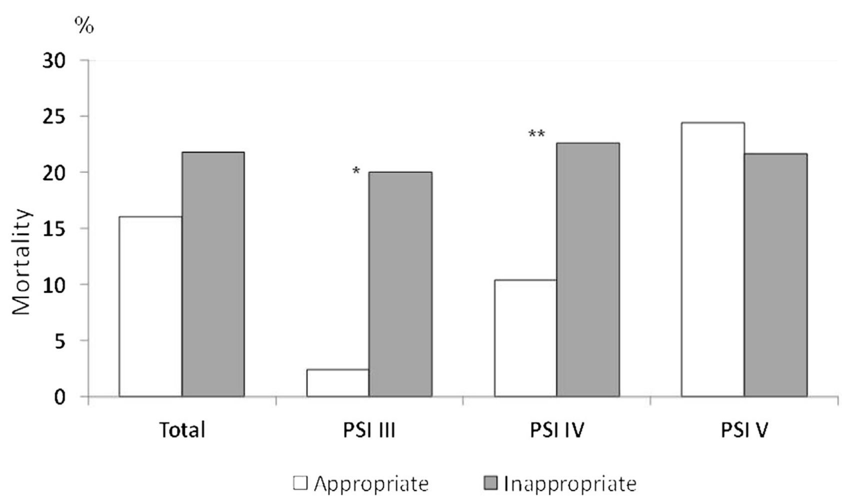

Figure 2 Incidences of inappropriate antibiotic use and in-hospital mortality among the PSI III—V classes. Higher in-hospital mortality rates of the patients receiving inappropriate antibiotic therapy compared with those with appropriate antibiotic therapy in the PSI III (**p* = 0.036) and IV (***p* = 0.058) classes. PSI = pneumonia severity index.

of whether or not the patients received inappropriate antibiotic treatment. Therefore, identification of risk factors beyond the PSI is mandatory to better predict the DRPs in patients with PSI III and IV.

Multivariate analysis was performed on the PSI III and IV classes. Nasogastric tube feeding (OR, 3.88; 95% CI, 1.75—8.60; $p = 0.006$) and bronchiectasis (OR, 3.12; 95% CI, 0.66—14.69; $p = 0.007$) were risk factors for DRPs in patients with PSI III and IV. The area under ROC of these two risk factors in patients with PSI III and IV was 0.651 (95% CI, 0.577—0.725).

The risk factors for MRSA were analyzed in the PSI classes, and the only significant difference was noted in the PSI V class, in which wound care was significantly associated with MRSA infection (OR, 3.57; 95% CI, 1.52—8.39; $p = 0.002$).

Algorithm of antibiotics selection by integrating PSI and risk factors

From the results of the current study, we suggest an algorithm for the selection of antibiotics for patients with HCAP as shown in Fig. 3. Antibiotic regimens for CAP may then be considered for patients with PSI II because of the low risk of DRPs. Broad-spectrum antibiotics covering *P. aeruginosa* are suggested for those with PSI III and IV with bronchiectasis and tube feeding. Antibiotics for MRSA should be considered in PSI V patients who

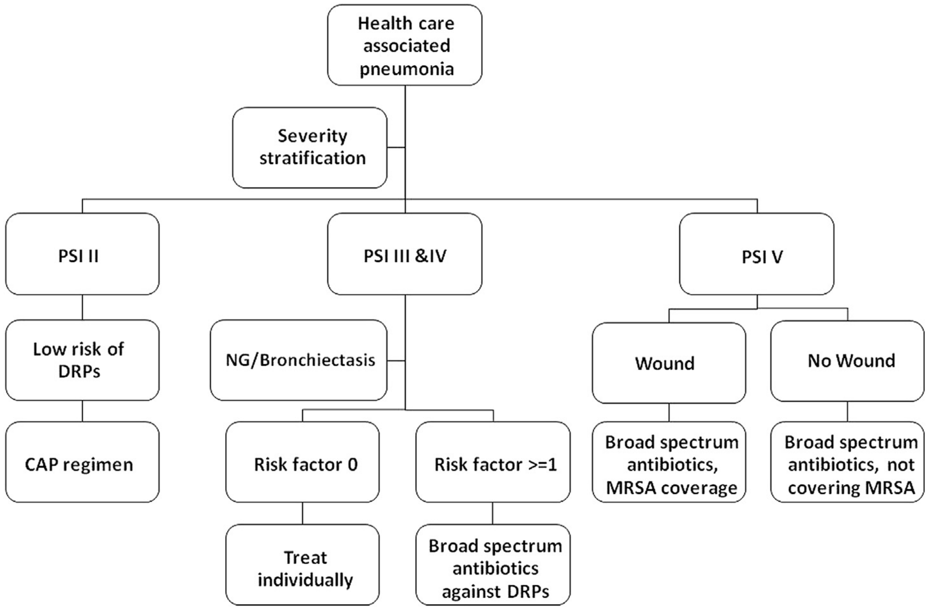

Figure 3 Proposed algorithm of health care-associated pneumonia therapy. Health care-associated pneumonia severity is first evaluated by PSI. Antibiotic regimens for community acquired pneumonia may then be considered for patients with PSI II owing to the low risk of drug-resistant pathogens. Board-spectrum antibiotics covering *Pseudomonas aeruginosa* are suggested for those with PSI III and IV with bronchiectasis or tube feeding. Antibiotics covering MRSA should be taken into consideration for PSI V patients who received wound care within 1 month, in addition to broad-spectrum antibiotics covering *P. aeruginosa*. CAP = community acquired pneumonia; DRPs = pathogens resistant to the treatment regimen of community-acquired pneumonia; MRSA = methicillin-resistant *Staphylococcus aureus*; NG = nasogastric tube feeding; PSI = pneumonia severity index.

received wound care within 1 month, in addition to broad-spectrum antibiotics covering *P. aeruginosa*.

Discussion

The results of this study showed that the PSI could predict both mortality and the risk of DRPs in patients with HCAP. However, there was a better performance when integrating the PSI with the risk factors for DRPs than PSI alone.

Previous studies suggested the key role of MRSA and *P. aeruginosa* in the pathogenesis of HCAP.[15,17,18] Hence, in 2005 the ATS/IDSA guidelines recommended anti-Pseudomonas plus anti-MRSA antibiotics as the empirical therapy for HCAP.[6] The current study also showed that *P. aeruginosa* was the leading pathogen in HCAP, and that MRSA had less of an impact on HCAP patients than in other studies. A similar result was reported in Taiwan by Wu et al,[19] who noted that the incidence of MRSA was only 7.8% in patients with HCAP. The widespread use of empirical anti-MRSA therapy for HCAP may not be cost-effective in Taiwan, and the current study showed that the risk of MRSA infection increased in patients with PSI class V and the comorbidity of wound care.

To our knowledge, there is no well-established severity scoring system for HCAP. Scoring systems for CAP severity such as the PSI, CURB-65, or severe community-acquired pneumonia have also been evaluated in the performance of predicting HCAP outcomes.[13,14,20,21] There were some debates about the performance of these scoring systems. Falcone and his colleagues[21] proposed that these scoring systems were less useful in patients with HCAP than in those with CAP. However, some investigators suggested that PSI had a better performance than CURB-65 in HCAP, which may be more related to the demographic characteristics and comorbidities of HCAP than CURB-65.[14,20] Our results showed the similar prediction power of PSI to those of previous studies.[14,16,20] Although the prediction power of PSI in HCAP was not as good as in CAP, PSI might be used as a severity scoring system of HCAP before a better one is developed.

Several risk factors of DRPs, but not pneumonia severity, have been reported in several studies.[9,10,15] However, some studies reported that a critical illness requiring intensive care or mechanical ventilation was a risk factor for DRPs.[7,22,23] Nevertheless, Shindo et al[24] reported that HCAP severity evaluated by the A-DROP scoring system (age, dehydration, respiratory failure, oriented consciousness, and low blood pressure) was not related to the incidence of DRPs. Conversely, our results demonstrated that the PSI in HCAP patients could predict the risk of DRPs. The advantages of the PSI over the A-DROP system were that some of the risk factors for resistant bacteria were included in its items, and that it also represents illness severity.

The current study reported that bronchiectasis and enteric tube feeding were additional risk factors beyond PSI in PSI III and IV patients. The integration of these two risk factors and PSI in PSI III and IV patients improved the predictive power of PSI for DRPs, which is comparable with the prediction power of Shorr et al's[22] and Aliberti et al's[8] scoring systems. The advantage of our model is that not only can it predict the risk of DRPs, but it can also predict in-hospital mortality.

Ewig and colleagues[25] proposed a new insight of HCAP, focusing on the importance of functional status and daily living activity levels in pneumonia treatment and classifications. Our results also support this viewpoint. One risk factor of DRPs in PSI III and IV, enteric tube feeding, implied poor functional status. Thereafter, functional status might play a more important role beyond the concept of HCAP and CAP treatment.

In the absence of culture data, early and appropriate empiric antimicrobial treatment is important to optimize outcomes.[26] This was also found in the current study, except for patients with PSI V. The most likely reason for this is that most patients with PSI V died owing to underlying patient-related factors and severe illnesses rather than the presence of antibiotic-resistant pathogens.[27] Another possible reason is the nonaggressive or limited treatment for HCAP. The lower use of advanced and intensive care including intensive care unit admission, mechanical ventilation, and the need for vasopressors have been reported for patients with severe HCAP.[28]

The patients with PSI II seemed to be a unique group. They were younger and had a better functional status, but a higher use of immunosuppressants and hemodialysis. They also had less microbiological evidence compared with other patients. The patients with negative culture results possibly had a lower severity of illness compared with those who had positive culture results.[29] This suggests that conventional therapy against CAP may be adequate for PSI II patients and may not lead to an increase in mortality rate.

A limitation to this study is that the microbiology data mainly came from sputum cultures, and there was little information about atypical pathogens such as *Legionella*, *Mycoplasma*, and virus. Interpretation of sputum cultures is confounded by the high rate of oropharyngeal colonization by aerobic gram-negative bacilli and *S. aureus*.[30] However, invasive procedures are not always indicated and feasible for HCAP patients, and aspiration of oropharyngeal secretions is usually considered a major risk factor for pneumonia in the institutionalized elderly. Therefore, microorganisms in sputum cultures may represent the causative pathogens. Another limitation of this study is that data on blood pH were only available for 362 individuals while calculating the PSI. If no data were available, a pH value of > 7.35 was assumed. However, this assumption may have had some impact on the PSI scores.

In conclusion, the PSI is useful not only in CAP, but also in HCAP, to evaluate the risks of mortality and resistant pathogens. If patients are stratified by PSI score and weighted by extra risk factors, more appropriate broad-spectrum antibiotics may be prescribed, thereby avoiding unnecessary antibiotic treatment and bacterial resistance.

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